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ABSTRACT

This paper considers some of the problems in implementing a cost-effectiveness analysis in training and education, and provides a specific example of an analysis that partially meets the cost-effectiveness analysis requirements. A computer-based study management system (SMS), which was implemented on a limited basis, was evaluated in the context of a Navy technical training school. A logical analysis was conducted of alternative delivery systems representative of the variety of delivery alternatives: minicomputer, time-sharing commercial system, and a microprocessor. Measures of effectiveness discussed included student study time, student attitudes, software development, facilities requirements, and hardware requirements. Cost considerations are mentioned only for hardware systems; other categories of resource requirements remain constant across systems. A cost-effectiveness tabular display is recommended for maximizing available information in the most easily interpretable form. (VT)

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EXAMPLE OF THE APPLICATION OF COST-EFFECTIVENESS TECHNIQUES IN A COMPUTER-BASED STUDY MANAGEMENT SYSTEM EVALUATION

by

Hervey W. Stern

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A Example of the Application of Cost-Effectiveness Techniques in a Computer-Based Study Management System Evaluation

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Introduction

Most training systems involve compromises in that the resources available for training and education are finite and can usually be expended on some alternative system. This is especially true of computer based instructional systems where resources allocations are large or, at least, are viewed by management as large resource consumers. Because of these resource limitations, it is desirable to examine a number of alternatives to determine how the funds might best be expended. A formal method for accomplishing this goal has evolved from earlier analyses conducted on allocating water resources. This evaluation, known as cost-effectiveness analysis, is an orderly and systematic means for specifying the worth of alternative methods of meeting the same goal. One of the basic assumptions of cost-effectiveness analysis is that there is no unique solution or set of resources that cannot be utilized in some manner. Most educational institutions are concerned with this allocation of resources, but alternative configurations are usually not considered. The object of an analysis is to provide a set of systematic observations of reasonable alternatives that management can address when considering the selection process. The purpose of this presentation is to consider some of the problems in implementing a cost-effectiveness analysis in training and education and to provide a specific example of an analysis that partially meets the cost-effectiveness analysis requirements.

The specific method under investigation is a computer-based study management system (SMS) that was evaluated in the context of a Navy technical training school. The research was conducted to assess the effectiveness of the SMS and no attempt was made to collect data from alternative delivery systems. This is a common occurrence due to the expense of evaluating more than one system. In many cases the cost is prohibitive, thus the analysis must be done on the basis of projected data and criteria measures that can be compared across systems without the need for physical presence of the equipment. As this was the case with this system, a logical analysis of alternative delivery systems was conducted.

The SMS is really an combination of two concepts, that of questioning techniques interspersed with study assignments as promoted by Rothkopf, (c.f., Rothkopf, 1970) and computer managed instruction (CMI). The concept of querying students to facilitate learning is not new but has received attention recently. The CMI concept provides a vehicle for automating the individualization necessary for effective presentation of the questions. The SMS is designed to maximize student participation in study assignments without requiring extensive revision of existing materials.

SMS Operations

To evaluate the SMS concept in an operational Navy training enviornment, one week of the Interior Communications "A" School was selected as a test vehicle for examining the effects of the SMS. Unfortunately, the week's training could not be completely reformated to maximize the individualized questioning techniques. Instead, the SMS was implemented at the end of the shortened classroom day as a test of the feasibility of the concept. At the end of the conventional instruction period, the students went to a room with eight computer terminals which were used for assessing student knowledge on a number of areas covered during the week's training. When the student felt he had adequately mastered the study material in question, he could request a computer administered quiz. If he could show adequate processing of the information, the student was then allowed to leave school for the rest of the day. If the student could not demonstrate adequate knowledge, he was required to study assignments given him by the computer and return for another questioning session.

Problem Origination

In a sense, the SMS is but one alternative strategy to the conventional instruction; several other strategies could be assessed. However, the question addressed is less broad. In this instance the results showed that a SMS even of limited configuration can provide a suitable alternative form of instruction. When considering the problem of implementing a SMS, the question then becomes which of several alternatives computer configurations can best meet the needs that arise with this specific instructional strategy.

When the research question was initially posed, NPRDC had been developing experimental programs on the PLATO IV system. Thus, the specific computer used in implementing the SMS evaluation was readily available with knowledgeable programmers on hand. Because of these powerful arguments in its favor, it was the obvious choice for this evaluation. However, it is but one of many alternative solutions which are amenable to cost-effectiveness analysis.

Specifying the Alternatives

The PLATO terminal is a sophisticated device that is designed to handle complex graphics displays and extensive computer assisted instructional activities. It is a centrally controlled, remote-site, multiuser system. As such, it has extensive capabilities not essential for SMS operations. Several alternatives could be considered. For this presentation, three types of systems were selected that are representative of the variety of delivery alternatives. One of these is a minicomputer that is used as a stand-alone operation. Another is a time-sharing commercial system which functions similarly to the PLATO system. Both of these alternatives have relatively simple display devices and, in the case of the minicomputer, smaller storage capacity. The other alternative considered is a microprocessor or "personal" computer. While this latter alternative is just now entering the market, their potential is too large to ignore. It probably is less flexible in its delivery modes than the other two systems.

Cost-effectiveness Analysis

Before examining the specific problem, a few comments on the general process are desirable. First, what it isn't: (1) It doesn't provide absolute, firm

solutions that void the decision maker's job. Cost-benefit analysis (as opposed to cost-effectiveness analysis) attempts to place dollar values on both costs and benefits to end up with a single value from a numerical ratio. However, many judgements have to be made prior to the determination of the final ratio which can bias the estimate. (2) It does not quantify the unquantifiable. For instance, when the auto industry asks the Department of Transportation to place a value on a human life, the auto industry, in essence, admits it is a difficult to impossible task and does not want to be personally responsible for determining the number. (3) It cannot make a probability into a fixed event. As long as there is some chance of alternative events occurring, estimates of the event occurring must be examined with care.

The cost-effectiveness analysis does provide:

(1) A method for systematically analyzing a number of alternatives that can be evaluated on a number of common criteria.

(2) A method for deriving a cost analyses of all alternatives.

(3) A means for developing descriptive, comparative and/or predictive analyses.

Measures of Effectiveness

Measures of effectiveness are difficult to objectively specify. They can easily bias the results by their wording. It is essential that an adequate number of criteria be chosen without being overly restrictive. Usually their number is limited to seven or eight, at most. In this instance, since the training strategies are not the main point of focus, the criteria were based on the acceptability of various computer configurations for implementing a study management system. They are:

- Student study time
- Student attitudes
- Software development
- Facility requirements
- Hardware requirements

Usually either cost or effectiveness levels are held constant and the other variable is allowed to vary. This may not be a realistic situation but is a goal that is strived for whenever possible. Obviously, it eases the decision-makers job. In this instance, it was possible to select systems that had fairly uniform costs, with one exception. Thus, the decision can be based on effectiveness measures. As stated earlier, it was not possible to actively evaluate all systems due to the resources required. The effectiveness criteria measures were interpolated from the findings on the PLATO system and by logical analysis and interpolation from other known system parameters. All measures are summarized in Table 1 along with the costs.

Insert Table 1 About Here

1. Student Study Time. In the military training world, student salaries are a direct cost related to training, so any reduction in time can be considered a benefit. The total average time for study and quizzes, excluding study time prior to the first quiz, was 20 minutes. The average time spent on line with the computer was 11 minutes. While there was considerable variability in these times, they can be considered representative of student text processing. In essence, some students completed the material on the first try, while others required repeated efforts to master the material. Whatever the computer system under consideration, the assumption is made that a more flexible SMS approach that allowed the student to access the computer whenever his studies called for it, would result in reduced time to master cognitive information. Although these times were obtained from the PLATO system, from the processing times of the other alternatives, it is felt that no significant increase in computer querying time would be required.

2. Student Attitudes. In general, it was found that students had a slight preference for conventional instruction over computer based questioning and self-study. They judged the specific study assignments useful, but felt the SMS reduced their study independence. No perceived change in study habits was reported. The microcomputer and time-sharing systems should produce similar results, but how the personal system would fare is difficult to project. It conceivably could meet with better reception for two reasons: (a) It isn't preceived as a large amorphous system that has control, and (b) the student could use it at his convenience in a less formal setting. All computer based systems may receive more favorable attitudes if longer exposures were possible. In this experiment, considerable time was necessary to familiarize the student with procedural activities.

3. Software Development. The basic programming requirement is a "driver" lesson that monitors student progress and makes appropriate assignments. For PLATO, which uses a high level author language, this effort required approximately one month of activity by both a programmer and psychologist experienced in other SMS applications. Question generation and entry into the computer was accomplished by a number of individuals, most of which were not experienced in programming. A total time of over 2600 hours was required to complete eight lesson quizzes. The minicomputer along with time-shared system would present a similar require-ment, although the systems communicate in lower level languages, which means a programmer is probably necessary for most work. The smaller personal units rely on languages such as BASIC which is satisfactory for uncomplicated programming applications such as the SMS so that someone who is unfamiliar with the PLATO authoring language probably could develop a BASIC program in approximately equivalent time. The end result is that the cheapest form of software development depends on the expertise of the programmer.

4. Facilities Requirements. The additional requirement is for sufficient floorspace to accommodate a number of computer terminals and study carrels

TABLE 1
SMS DELIVERY DEVICE CAPABILITIES

CHARACTERISTIC	PLATO IV	MINICOMPUTER	COMMERCIAL	MICROPROCESSOR
1. Student Studytime				
a. Potential for reduced studytime.	Very good, fast processing time.	Adequate	Very good	Could be slower than others, depends on demand
2. Study Attitudes				
a. Computer controlled questioning.	Satisfactory, could be viewed more favorably.	Potentially better than PLATO because of local control.	Same as PLATO	Potentially high with high degree of control.
b. Study independence.	Computer controls where & how studies.	Same as PLATO	Same as PLATO	Computer controls how S studies.
3. Software Development				
a. Ease of development	Relatively simple task.	Requires more knowledge than PLATO.	Requires more knowledge than PLATO.	Requires more knowledge than PLATO.
4. Facilities				
a. Floorspace	Sufficient for 24 terminals & study correls.	Computer space with suitable air conditioning, 24 terminals and study correls.	24 terminals & study correls.	Space for study correls which would accommodate individual units, or space in S's quarters.

Table 1 - Continued
SMS DELIVERY DEVICE CAPABILITIES

CHARACTERISTIC	PLATO IV	MINICOMPUTER	COMMERCIAL	MICROPROCESSOR
5. Hardware				
a. Display format.	Exceeds any SMS need.	Adequate	Adequate	Adequate
b. Data collection.	Adequate	Adequate for most uses.	Adequate	Limited storage.
c. Independent operation.	Centrally located mainframe, requires phone line data transmission.	Local control.	Out-of-house mainframe, phone lines required.	Controlled by individual, student must learn all operations.
d. Memory availability.	Usually adequate.	Adequate	Adequate	Might need expansion, but feasable.
Discounted annual costs based on a ten year life cycle.	$195,000	$14,000	$16,500	$15,000

necessary for the SMS operation. In the case of the personal system, this additional requirement is not necessary, either the classroom or some distributed set of locations is advisable.

5. Hardware Requirements. As mentioned previously, the PLATO system is designed for large scale operations. The terminals have extensive capabilities that are not essential for SMS operations. Data collection files can be designed, but use relatively large amounts of core storage. Operation requires leased phone lines which can cause operational problems. If the program is large, access to sufficient core may have to be scheduled in advance when large numbers of users are on the system. A time-sharing commerical system operates essentially as does the PLATO system. It involves renting space on a local, variable size system to operate, in this example, user owned terminals. The terminals are those found in stand alone minicomputers which are less flexible than PLATO terminals, but capable of handling all SMS operations. This system has the advantage over a minicomputer of faster operational time, but control of the main frame is in the hands of an outside source. The minicomputer, on the other hand, maintains local control of core usage, but requires all maintenance be planned by the owner. The other alternative is just becoming feasible, so the data is less stable. Hobbyists have demonstrated that the microprocessor configuration is possible at this time, however its feasibility on a large scale is just becoming a reality. The main drawback is a lack of computational power, which translates into longer response time. However, the relatively undemanding nature of most SMS operations reduces the need for large core storage, unless large amounts of data need to be collected. The advantages are portability and individual control over the computer operation. This system could conceivably be operated from any location, such as student quarters. In this case it would be possible to drive an ordinary TV screen, with suitable modifications. Another potential application is to use the microprocessor to drive a videodisc, which in turn drives the TV screen. This latter option provides extensive graphic and animation capabilities.

Cost Considerations

Although it is possible to extract several categories of resourse requirements, to some extent they will remain constant across systems. The major exception is the cost of the hardware systems. To simplify this example, only these costs are presented. These costs have been analyzed in accordance with accepted Department of Defense economic analysis and program evaluation techniques as documented in Secnavinst 7000.19A(1975). This means that the costs for each alternative are specified over the life cycle of the system, in this instance for initial investment and operation. A discount rate of 10% was used to determine life cycle costs. A life span of ten years was used for all three systems. This length of time may be needed to justify the initial hardware costs, yet the equipment may be obsolete before the end of this period. Because this data is difficult to project, the ten year period was arbitrarily selected. All costs are based on the purchase of equipment sufficient to operate 24 terminals on a 40 hour per week basis.

(1) PLATO. To operate this system in San Diego, the following conditions must be met: (a) purchase time on the Control Data Corporation (CDC) timeshare computer in Los Angeles, (b) lease phone lines from Los Angeles to

San Diego, (c) purchase terminals, and (d) contract for maintenance of all equipment. Based on these requirements the initial terminal purchase price is $264,000 and the annual operations budget is $262,800. The annual discounted cost for the ten year life cycle would be $195,000.

(2) Local, Time-share system. This system operates under a slightly different set of requirements: (a) purchase core access time on a locally available large scale system, (b) lease local phone lines, (c) purchase terminals, and (d) contract for maintenance. These requirements can be met with an initial purchase price of approximately $36,000 and an annual operating cost of $20,000. The annual discounted cost is $16,500.

(3) Minicomputer. In this instance, it is necessary to purchase a computer and the peripherials necessary for operation plus provide maintenance for the system. This calls for an initial outlay of approximately $50,000 plus a yearly operation fee of $14,500. The annual discounted cost of this system is $14,000.

(4) Microprocessor. This category is much more difficult to specify because the product is just coming on the market and most manufacturers are not certain about the marketing directions. Obviously, there is a vast potential in the educational area. An example is the newly available Heathkit H.11 computer. A package system with limited memory, video terminal and suitable interfaces retails for $2500 bring the initial capital outlay for 24 stations to $60,000. While it is difficult to estimate maintenance, a figure simular to the mini-computer should approximate the costs, as the Heathkit is partially based on DEC PDP-11 hardware. Thus, the annual discounted cost would be approximately $15,000. This price does not include assembly of the computer and probably does not include adequate memory storage, however it is illustrative of the level of cost involved. Another system just entering the market in Radio Shack's $600 system. This cost is misleading as this system appears to need several additional peripherals for adequate SMS operation.

Final Considerations

The basic premise of this analysis was that comparable systems could be selected that were relatively constant in cost. Examination of Table 1 shows this is true for three of the systems, while PLATO obviously falls into a different category. This is not surprising as the cost-comparable systems were selected with this goal in mind, whereas the PLATO system was used as a demonstration vehicle to examine the feasibility of implementing a SMS without regard to acquisition cost. Obviously, any of the three small systems could conceivably be used, selection is dependent on the training emphasis and the needs of management. The function of the decision maker in this situation is one of weighting the SMS delivery device characteristics in proportion to the needs of the school. For instance, if classroom space is at a premium, the most mobile system would be the likely candidate, in this instance the microprocessor. With the data displayed as in Table 1, management also has the prerogative of equating these outcome measures and taking others into account. It is possible that local availability of a hardware distributor could be important and weigh in the final selection. When the data is displayed in the form of a single number this kind of decision becomes more difficult. The cost-effectiveness tabular display as shown in Table 1 is recommended for maximizing the available information in the most easily interpreted form.